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DESIGN AND DEVELOPMENT OF A SEAMLESS KEVLAR TUBE FOR EXPERIMENTAL COLLAPSIBLE FUEL STORAGE CONTAINERS

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This report covers the development of a circular seamless weaving technique to produce a basic Kevlar cloth suitable for collapsible fuel tanks. An 80-inch lay-flat tube was produced and four (4) experimental tanks were manufactured.

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I INTRODUCTION

This report covers the development effort relating to a circular seamless weaving technique to produce a basic Kevlar cloth tube suitable for collapsible fuel tank construction.

In the past, the generally accepted method of fabricating collapsible Fuel Storage Containers has been to utilize roll good materials that are machine coated, which are then cut, seamed, and vulcanized into a finished product.

The desirability to increase performance and miniminize potential problems of seam failures can be accomplished by eliminating all of the seams except for the end closures through the utilization of a woven tube.

In addition, the desire to increase storage capacity of collapsible fuel containers by retaining current ground contact areas and container dimensions can only be accomplished through higher fuel heads. Since the container fabric stresses are directly proportional to the tank height squared, as shown in the formula below, stronger materials are required to accomplish this without increasing fabric thickness and weight.

$$T = W\left(\frac{h^2}{4} + \frac{ah}{2}\right)$$

T = fabric stress, lbs/in.

W = fluid density, lbs/in.

h = Tank height, inches

a = fluid height in stand pipe, [illegible]

Utilization of Kevlar yarns in the base cloth offers a significant strength improvement over nylon, therefore, the primary objective of this development effort, was to develop a weaving technique to produce a seamless Kevlar tube cloth.

Four (4) 80-inch square lay-flat experimental fuel containers were fabricated from a 2 x 1 modified oxford weave tube cloth. The containers were coated with a new polyurethane elastomer having improved hydrolitic properties.

II OBJECTIVES

The primary objective of the R & D effort was to develop a weaving technique to produce a seamless Kevlar cloth tube, suitable for use in the construction of collapsible static storage fuel containers. In addition to the development of the weaving technique, the R & D effort was also directed towards application of a post weave cloth adhesive treatment.

III SUMMARY

Four (4) experimental 80-inch lay-flat experimental fuel containers were manufactured by GAC from a seamless Kevlar tube cloth as developed under this contract by Huyck Research Center per GAC and specification requirements.

The primary objective was to develop a weaving technique for a seamless Kevlar tube cloth suitable for use in static storage fuel containers.

Many experimental samples were produced, tested and evaluated with a 2 x 1 modified Oxford weave cloth selected as exhibiting the best overall desired physical and visual properties. The problems encountered with the tubular cloth related primarily to edge damage in the fill yarns. The filament damage in the fill yarns was also more noticeable on the plain and 2 x 2 basket weaves. Applying a very light wax coating to the warp yarns showed some but no significant improvement. Changes and refinements in loom tuning by Huyck greatly improved cloth appearance over the initial samples. Some of the problems in filament damage at the edges is directly related to the laboratory looms used to produce the 80-inch lay-flat tube. It is felt that production type loom equipment which is equipped with the latest edge formation technology could produce an acceptable tubular cloth.

Tubular cloth finish is very important when the elastomer is applied by the spray process, since the elastomer adheres to raised broken filaments and thus produces a very rough surface finish. In addition more elastomer is required for smooth even coverage which increases the coated fabric weight.

The area requiring additional effort is in the method of applying and drying the adhesive. GAC applied the adhesive by spraying and then hanging the tubes in drying areas. This approach would not be possible on large production seamless tubes.

The capability of weaving a seamless Kevlar tube cloth has been demonstrated; however, additional refinements are required before utilizing this approach

III SUMMARY (Cont'd)

on a quantity production. The next step should be to produce a large tube on a production type loom to determine if edge formation is improved and filament damage is eliminated.

The test data shows that the requirements of the specification were generally met and appear to be reasonably attainable goals.

A new polyester polyurethane with improved hydrolitic properties was used in the fabrication of the containers. The container weights were approximately 37 pounds each, which is slightly heavier than anticipated and is due to more coats of spray passes being applied to obtain even coverage over the filament damaged areas.

The experimental fuel containers should perform satisfactorily in the field test and appear to be structurally sound.

Refinements of the weaving, finishing (adhesive application), and handling of the seamless tube cloth will be required so that finished quality is in line with roll width goods.

It appears that the goods of the R & D effort in producing a basic seamless Kevlar tube cloth have been achieved with additional refinements being desirable.

IV DISCUSSION

A. Kevlar Tube Cloth Development

The physical characteristics of the Kevlar cloth as established by the Purchase Description titled; Tank, Experimental, Elastomeric Coated Kevlar Fabric, Collapsible, For Liquid Petroleum Fuels (dated 2 December, 1976) are listed below.

Characteristics of Kevlar Cloth 1/

PROPERTY	REQUIREMENT	TEST METHOD OF FED. STD. NO. 191
Thread count, warp & fill	36 x 36 (min)	5050
Weave	2 x 2 Basket	Visual
Weight	Record	5041
Thickness	.025 inch (max)	5030.2
Tearing strength, warp & fill	200 pounds (min)	5134 1/
Breaking strength, warp & fill	1300 pounds/inch (min)	5104 2/
Weathering resistance, after 100 hrs. exposure at 1% elongation	50% retention of initial breaking strength (Min)	5804 3/ 5104

Footnotes:

1/ The edges of the tear-test specimen shall be coated by dipping into or brushing with an adhesive that will preclude yarn slipping while under test (see 6.4)

2/ Ends of specimens for Breaking Strength Test shall be coated by dipping into or brushing with an adhesive that will preclude yarn slipping under test (see 6.4). Only those parts that are to be held in the clamps during test will be so treated.

3/ Alternate Corex D filters removed. Specimens shall be raveled for Method 5104 after accelerated weathering.

IV DISCUSSION (cont'd)

For the purpose of evaluating and determining optimum fabric performance, weave patterns other than those specified in Table I of the Purchase Description were evaluated. Goodyear Aerospace Corporation (GAC) initially established purchase specifications for a 2 x 2 basket and a plain weave Kevlar tube cloth.

The initial woven Kevlar tube cloth sample showed severe warp filament breakage and yarn piling in the 2 x 2 basket weave using 1000 denier, 1.5 tpi Kevlar warp and filling in a 36 x 36 construction. The filament damage was attributed to a combination of several factors, namely the fragile nature of the Kevlar yarns which were woven without sizing or other protective coating; the severe working of the warp yarns during insertion of 72 picks per inch total (top and bottom cloth); and possible marginal loom settings. The Kevlar tube cloth showed progressively worse yarn damage toward the loom edge which made it unacceptable for use in PILLOW tanks.

In a meeting with GAC, Huyck Research Center personnel, and the contracting office's representative, various approaches to improve the quality of the Kevlar tube cloth were selected. These items are expanded upon below in the sequence in which they were tried.

1. In place of the 2 x 2 basket weave with a count of 36 x 36 using 1000 denier yarns in both directions, the filling was constructed with two 1000 denier yarns plied together with a very low twist angle to produce a 2000 denier yarn with good flattening characteristics. This yarn was woven at 18 picks/inch filling in an Oxford weave to produce a fabric which very closely resembles the original basket weave fabric. This construction reduced the abrading action of heddles, reed, and shuttle to one-half of that occurring in the initial construction. This reduced warp working reduces warp yarn damage in the loom. No change in physical characteristics were expected other than a very modest increase in thickness.

IV DISCUSSION (cont'd)

2. A very light application (probably less than 0.1% by weight) of a parafin base wax known to be effective in reducing Kevlar abrasion was applied to the warp yarn as it entered the loom shed. The effects of wax treatment on coating adhesion and other properties were evaluated by GAC.

3. Attempts were also made to produce plain weave fabric at 36 ppi with 1000 denier and also at 26 ppi with 1500 denier filling yarn.

As a result of the meeting, Huyck Research Center produced four (4) Kevlar tube samples incorporating the changes outlined above. The samples produced were as follows:

a. 36 picks/inch, 1000 denier Kevlar filling in a 2 x 2 basket weave (per the original specification)

b. 26 picks/inch, 1500 denier Kevlar filling in a 2 x 2 basket weave.

c. 18 picks/inch, 2 ply 1000 denier filling in a modified Oxford weave.

d. 24 picks/inch, 1000 denier Kevlar filling in a plain weave.

GAC's evaluation of the above samples indicated that the 1500 denier Kevlar filling in a 2 x 2 basket was too sleeze and the plain weave fabric did not have sufficient picks to obtain the required tensile strength.

The two fabrics that showed the most promise were the 2 x 2 basket with the 1000 denier Kevlar filling and a modified Oxford weave. The edges of the loop samples were lightly singed by hand. Singeing of the broken filaments did not greatly affect the appearance of the sample fabrics

IV DISCUSSION (cont'd)

Small samples of the 2 x 2 basket (1000 denier) and the modified Oxford were polyurethane coated to determine the sprayability of the fabric. Both fabrics had many broken filaments to which the spray coating adhered, resulting in a very rough surface finish. The broken filaments were more discernable after the cloth was spray coated.

This type of cloth appearance is not acceptable for the spray coating since it requires the buffing of the broken filaments after the initial spray coat to obtain a smooth surface.

Since none of the preceeding samples included a light wax application on the warp yarns and since the broken filament problem still existed, Huyck Research Center produced two (2) additional modified Oxford cloth samples which consisted of (1) a light wax application on the warp yarns, and (2) a finer tuning of the weaving looms.

Screening tests for tensile, elongation, tear, gauge, and weight showed the modified Oxford weave cloth to meet the specification requirements, except for marginal tensile strengths at the loop turn-around edge.

Huyck Research Center produced the above two (2) samples in late November 1977. Examination of these samples showed a marked improvement in the amount of filament damage at the tube edges. However, broken filaments were still present at the edges in both the waxed and non-waxed yarns. Attempts to burn or singe the broken filaments did not improve the appearance, in fact, singeing produced a rougher texture or finish. Tests also indicated that singeing affects tensile strength.

The samples were also evaluated for sprayability and for the effect the light wax application might have on coat adhesion. Spray coating the cloth with a new polyurethane elastomer produced a very rough surface finish caused by the spray adhering to the broken filament yarns. A closer examination revealed that the adhesively treated cloth produced a rougher finish, than the non-treated cloth. Normally the adhesive is

IV DISCUSSION (cont'd)

applied to the cloth either by dipping or spraying. To expedite these samples the adhesive was brushed onto the cloth. It appears that brushing caused the broken filaments to be raised, thus amplifying the broken filament problem. The experimental tanks were produced by spraying.

A review of the tensile and tear strength data on the experimantal coated fabric shows that the tensile strength of the coated fabric was reduced significantly in the fill direction at the edge turnaround of the woven tube, while warp and fill tensile strength in the center sections were within the minimum specification requirements. Differences in pick lengths in the fill direction and fill thread alignment from top to bottom of the tube at the edge, which produce a curved test specimen appeared to be the cause for low fill tensiles. The misalignment and pick length variations resulted in individual yarn breakage and edge loadings due to the low elongation of the Kevlar cords. The coating locks up the cloth; so that individual yarns begin to break on the one-inch wide test specimen. Test data on the cloth for the turnaround edge showed that the tensile strength at the edges met the specification requirements except for the singed edge sample.

A review of the edge tensile data indicated that the strength reduction could be attributed to small differences in pick lengths which are concentrated at the loom edges. Uncoated filling tensile strength tests indicate that yarn damage by weaving is insignificant. It appeared that the coating immobilized the filling yarns so that slight localized irregularities in pick length resulted in lower tensile strength on the coated fabric edges. Huyck Research Center adjusted their tube cloth in order to improve and perfect the cloth edges. It was pointed out by Huyck that the loom used for the 80-inch tube is not fitted with the latest edge formation equipment which does exist on larger production looms.

IV DISCUSSION (cont'd)

The adhesion data showed that the light wax application on the warp yarns did not affect the coat adhesion levels of the treated cloth. The slight wax application appeared to give a better fabric finish, therefore this process was incorporated into the cloth purchase specification for the experimental Kevlar PILLOW tanks.

As a result of discussions with Huyck Research Center personnel, it is felt that further efforts to improve the Kevlar cloth finish would not have been meaningful on the current equipment. GAC therefore, released Huyck to complete the weaving of tube cloth as required for this development effort. It should be pointed out that the weaving improvements from the initial rough samples to the current modified Oxford weave finish cloth were significant.

The production run of the 80-inch lay-flat modified Oxford weave Kevlar tube was inspected for fabric defects, edge fraying, broken filaments, lay-flat width, and general appearance. The visual inspection revealed broken filaments, throughout the tube, which were particularly noticeable at the edges. The general appearance of the woven tube was much improved over the many earlier samples produced by Huyck. Edge fraying and filament damage was also improved. The lay-flat width averaged between 78 1/2 to 79-inches. Broken filament damage was greater on the exterior than on the sleeve interior.

Spraying small samples of cloth with elastomer accentuated the broken filament problem, in that it produced a very rough surface caused by the elastomer adhering to the raised broken filaments.

Singeing of the cloth after adhesive application burns off most of the broken filaments; however, some additional buffing is still required after application of the polyurethane elastomer.

A meeting was held at GAC on March 29, 1978 between Huyck, GAC and the contracting officers representative to inspect the woven Kevlar tube

IV DISCUSSION (cont'd)

cloth and to review the developments of the weaving process. The seamless Kevlar tube development effort demonstrates the technical feasibility of weaving a basic cloth tube suitable for collapsible fuel tank construction. Additional development effort is required to reduce warp yarn damage in the weaving process.

Huyck personnel expressed the opinion, that filament damage would be greatly reduced on production loom equipment, which is equipped with ultimate edge formation technology.

B. Kevlar to Polyurethane Adhesive

Adhesion samples were prepared using previously developed GAC Kevlar to polyurethane adhesive. For the initial screening tests the drying conditions and concentration of ingredients were varied. The data on these initial samples is reported in the following two tables.

Adhesive	Bake Time & Temp.	Original (lbs/in)	Dry Heat @ 140°F (lbs/in)	72 Hour Soak in Medium #5 (lbs/in)
Untreated		13.5/11	/10.6	7.5/5.2
D-1660-F-484	5 @ 250	20	21/25	10.5/14.5
"	20 @ 250	27	21/28	9.5/13
"	5 @ 325	23/27	24/28	11.5/14.5
"	20 @ 325	22/28	25	
"	5 @ 400	20/17	24	14/15.5
D-1660-F-485	5 @ 250	13/19.5	12/14	7.5/7.7
"	20 @ 250	12/16.5	10.5/19.5	7/6.5
"	5 @ 325	11.5/15	10/13	7.2/7.2
"	20 @ 325	13.5/12.5	15/12.5	7.8/10
"	5 @ 400	14.5/18.5	11.5/15	9.5/7.5

IV DISCUSSION (cont'd)

Adhesive	Original 75°F & 50% R.H. (lbs/in)	Dry Heat @ 140°F (lbs/in)	72 Hour Soak Medium #5 (lbs/in)
139-1 (D1660F484)	28/36	16/-	11/-
139-2	19/23	15/-	6.5/-
139-3	28/32	14/-	9/-
139-4	30/30	14.5/34	9/-
None	11.5/13.5	13/17.5	7.5/9

NOTE: Adhesive bake time and temperature for samples was 5 minutes @ 250°F.

During fabrication, air bubbles were trapped in the adhesive between the two plies of the adhesion test samples listed in the above table. Upon testing the samples failed at the weakest interface, which contained the air bubbles. As a result, accurate fabric adhesion values could not be obtained for these samples. The fuel soak and heat aging apparently effected the bubbled interface.

A new set of adhesion samples were prepared using a fabrication process that eliminated the air bubbles in the adhesive. This allowed the accurate determination of the adhesion level and prevented serious deterioration by the fuel soak and heat aging. The test results of the new samples are listed in the table below.

Adhesive	Original 75°F & 50% R.H. (lbs/in)	Dry Heat @ 140°F (lbs/in)	72 Hour Soak Medium #5 (lbs/in)
139-1 (D1660F484)	32/39	33/67	31/34
139-2	33/36	48/53	36/32
139-3	35/56	45/54	23/25
139-4	35/47	48/60	32/32
None	13/15	6/6	14/13

NOTE: Adhesive bake time and temperature for samples was 5 minutes @ 250°F.

IV DISCUSSION (cont'd)

All of the adhesive screening tests were conducted using an available Kevlar cloth. Based on the data and past experience, the 139-1 (1660F484) adhesive was selected for the experimental Kevlar containers.

Adhesion data for samples fabricated from the seamless Kevlar tube cloth for both wax bar treated and non-treated (see Section IV A) filling yarns indicated no appreciable difference in adhesion levels. Therefore, the wax bar treated filling yarns could be utilized if a decrease in the amount of yarn damage were noticeable.

The adhesive can be applied either by brushing, rolling, dipping or spraying. However, in the final container fabrication process, the spray application was utilized, since brushing and rolling accentuated the filament yarn damage.

C. Container Fabrication

The experimental 80-inch lay-flat containers were fabricated from the 2 x 1 modified Oxford weave Kevlar tube cloth. The adhesive was applied by spraying to minimize the raising of the broken filaments which were more noticeable after adhesive application. Attempts to singe the broken filaments after adhesive treatment did not significantly improve the sprayability of the cloth.

From a visual viewpoint the cloth appearance was good; however, upon spraying, the adhesive of the elastomer to the filaments produced a very good rough surface finish. This required each spray pass of the elastomer to be buffed and sanded.

The elastomer coating material utilized in the manufacture of the experimental fuel containers and samples was a new polyester polyurethane having improved hydrolytic properties. The exterior bottom of the containers are overcoated with a coat of polyester polyurethane to provide for better fungus resistance.

IV DISCUSSION (Cont'd)

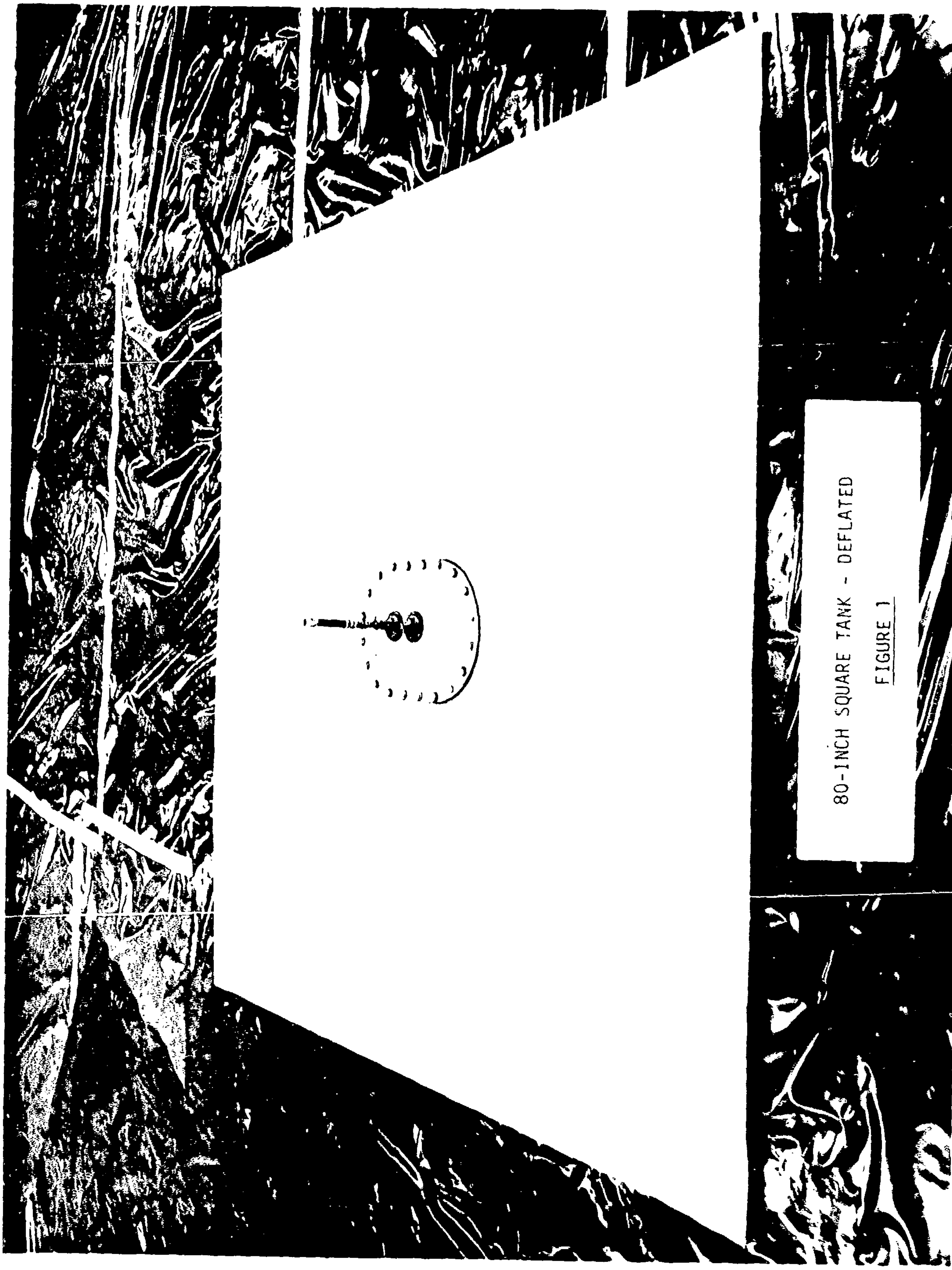
A 16-inch by 10-inch oval compression type fitting with dual flanges was incorporated into the center of each tank to provide for access and attachment of fill and discharge hardware as required. The compression fitting is shown on Goodyear drawing ADP8001745.

A cross-section of the completed fitting assembly including the fabric flanges is shown in Figure 5.

Figures 1 through 3 show the finished experimental containers in a flat and inflated condition. The approximate finished weight of each container was 37 pounds.

The ends of the container tube were closed with a 5-inch lap type seam. The corners were closed and sealed against leakage through the use of special fabric tabs left in the end seam flap.

The size of the containers, location of fittings and handles were as shown in Figure 4.

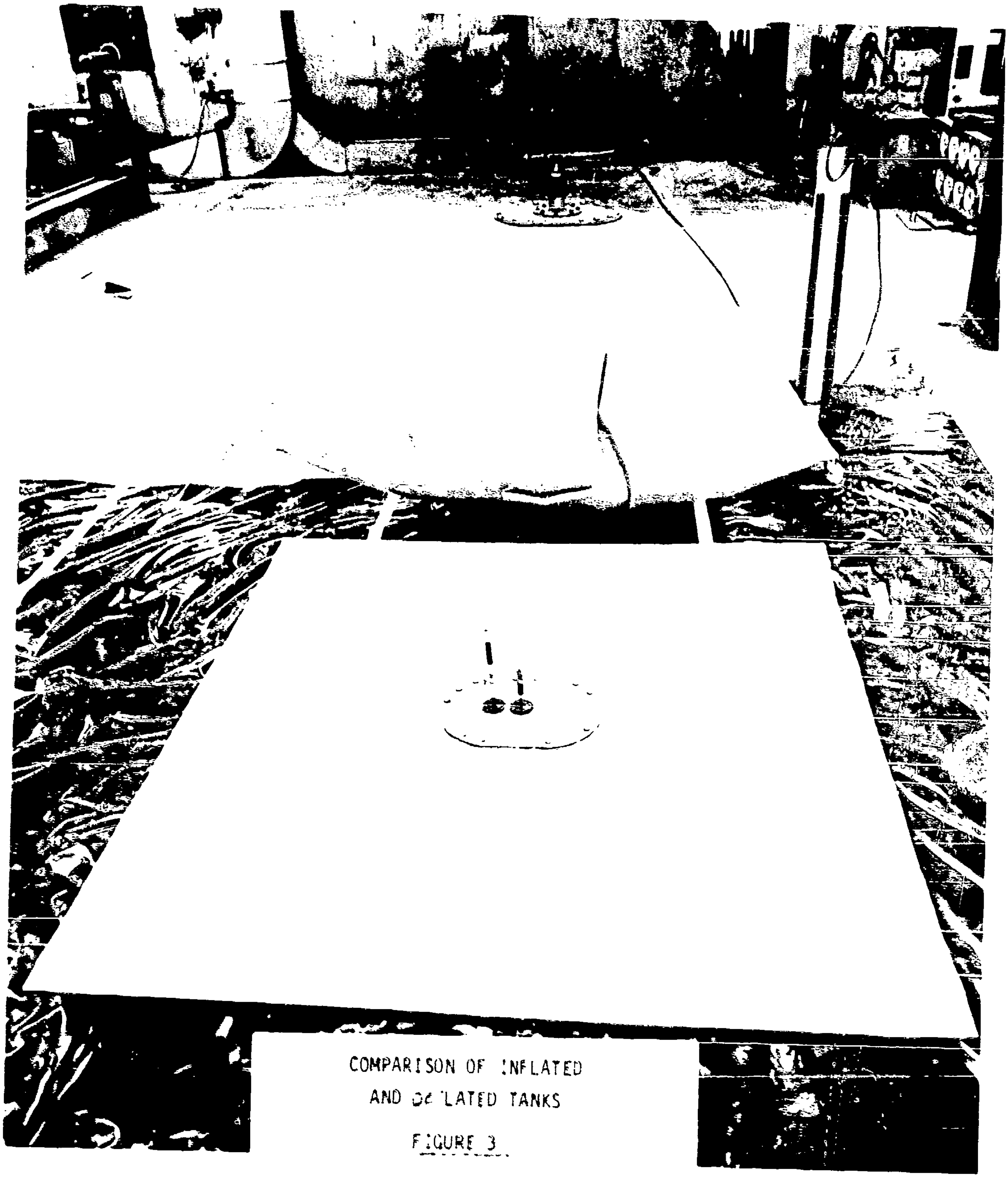


80-INCH SQUARE TANK - DEFLATED

FIGURE 1

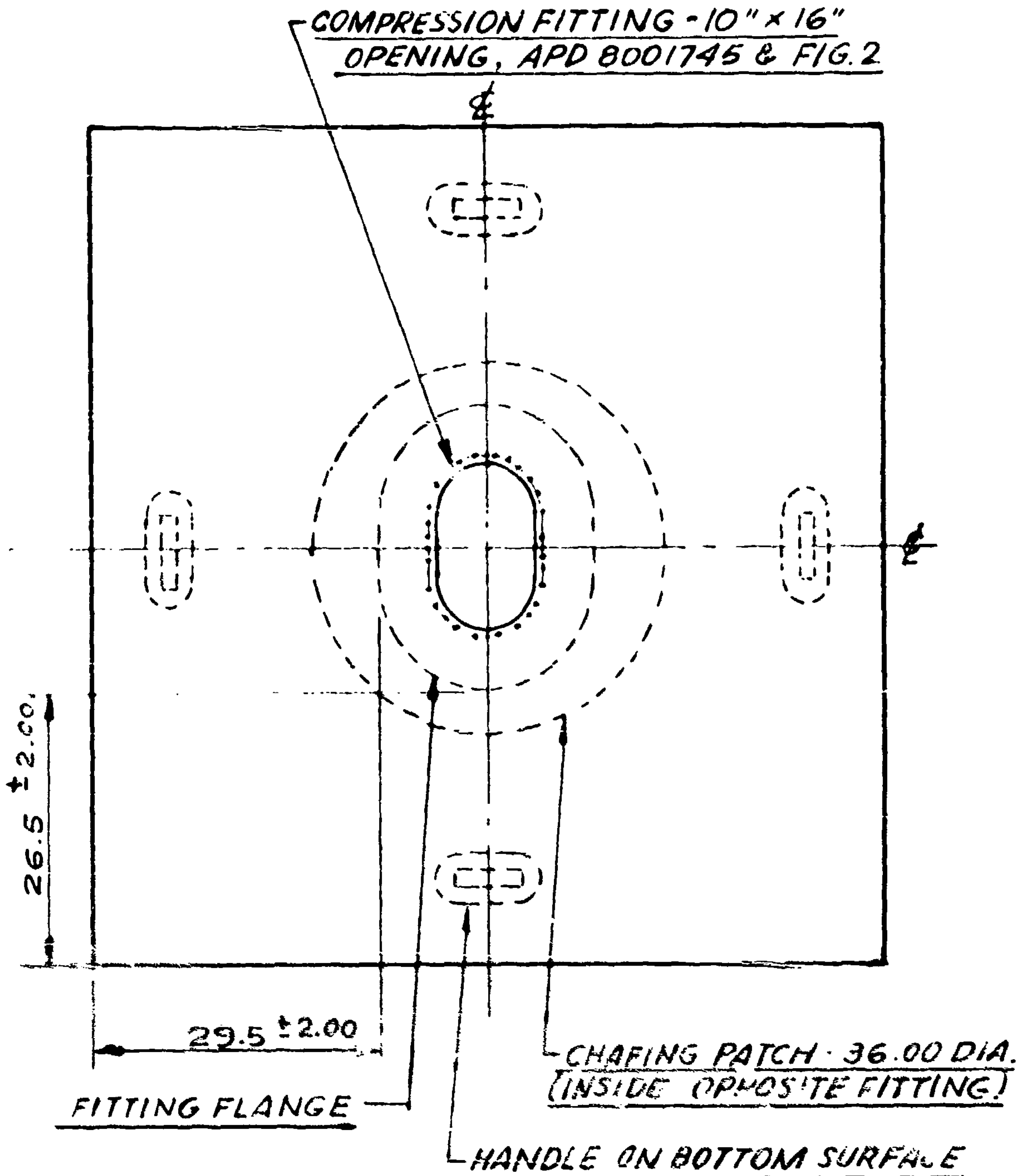
TANK ON PRESSURE TEST

FIGURE 2



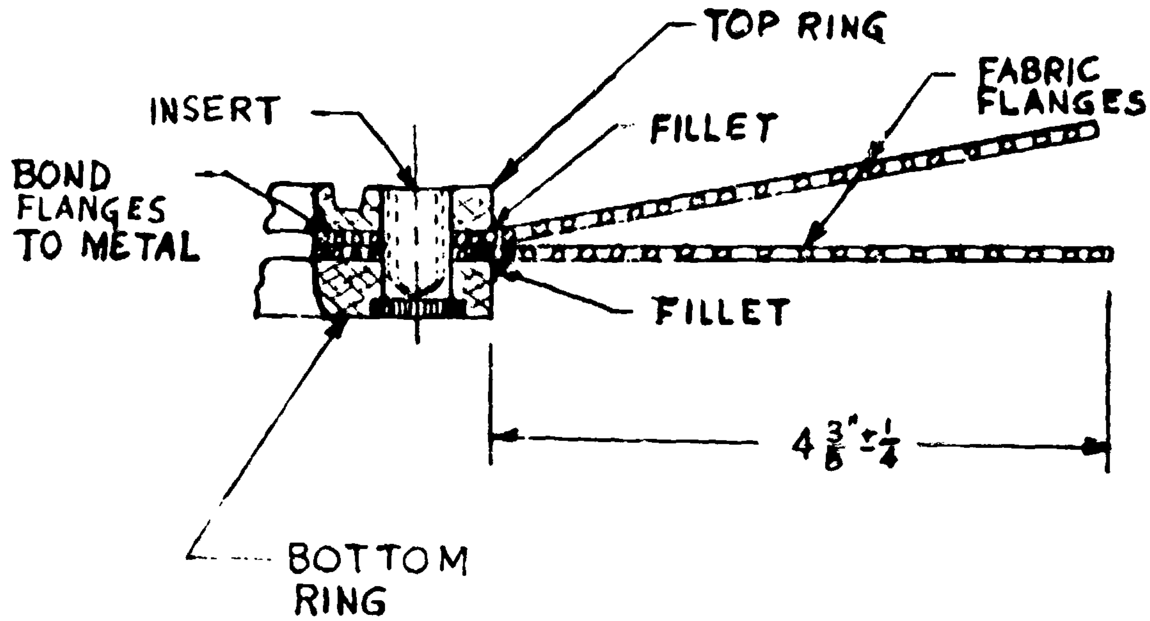
COMPARISON OF INFLATED
AND DEFLATED TANKS

FIGURE 3

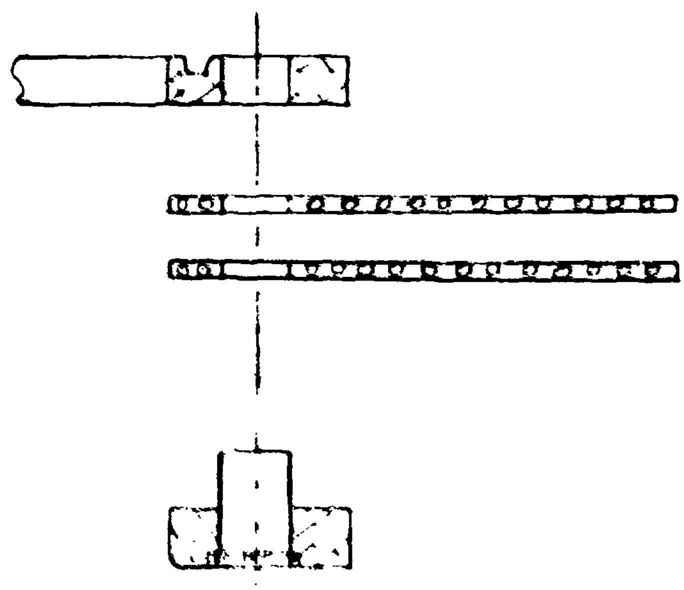


EXPERIMENTAL KEVLAR PILLOW TANK
SIZE: APPROX. 80 IN. SQUARE

FIGURE 4

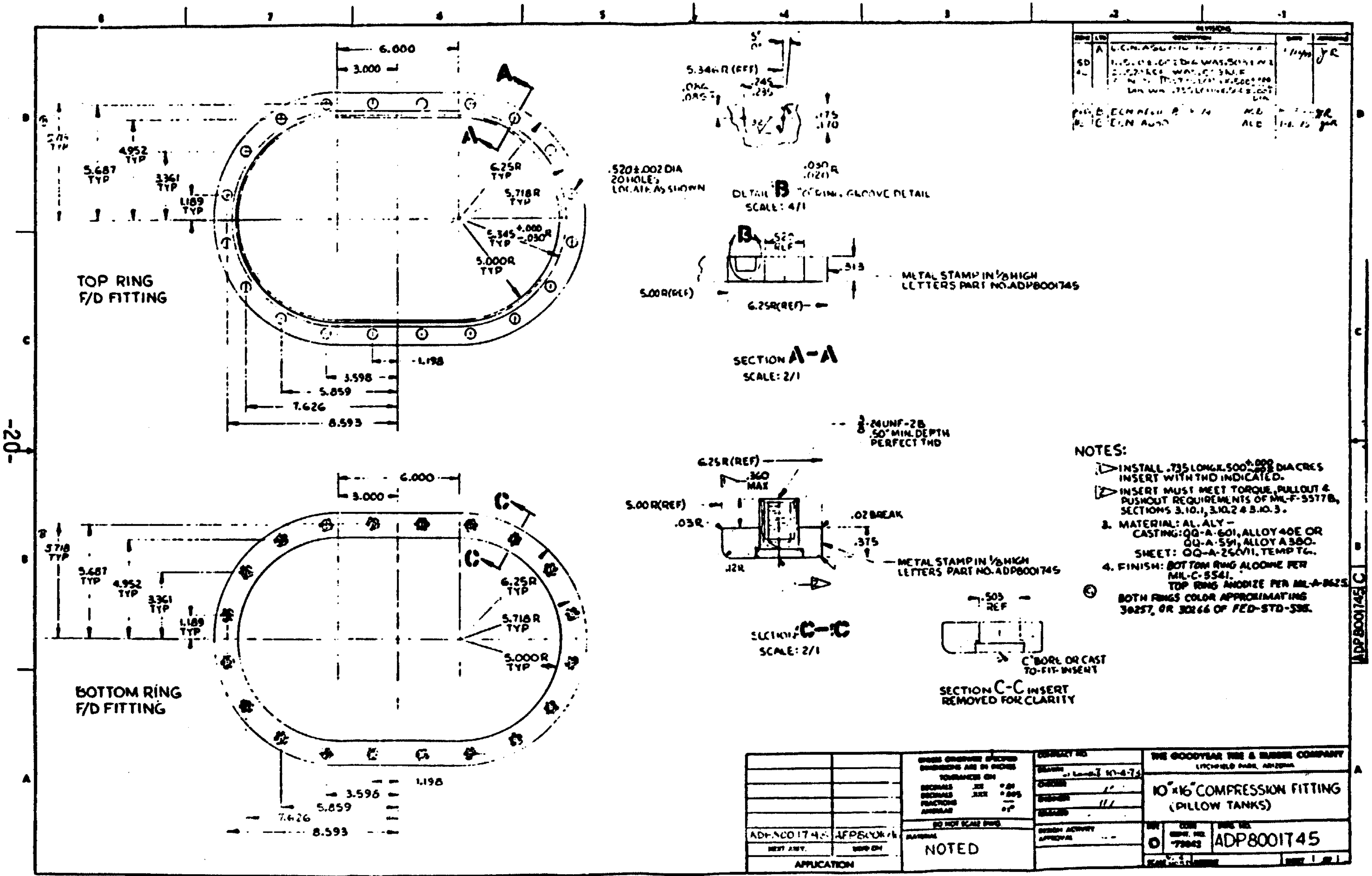


SECTION THRU FITTING ASSY.



EXPLODED VIEW

FIGURE 5
FITTING ASSEMBLY


TOP RING
F/D FITTING
BOTTOM RING
F/D FITTING
6.000
3.000
4.952 TYP
5.687 TYP
3.361 TYP
1.189 TYP
6.25R TYP
5.718R TYP
5.345 TYP
4.000 -.030R
5.000R TYP
1.198
3.598
5.859
7.626
8.593
.520±.002 DIA
20 HOLES
LOCATE AS SHOWN
5.346R (EFF)
.245
.235
.175
.170
.030R
.020
DETAIL B O-RING GROOVE DETAIL
SCALE: 4/1
5.00R(REF)
6.25R(REF)
.313
METAL STAMP IN 1/8 HIGH
LETTERS PART NO. ADP8001745
SECTION A-A
SCALE: 2/1
3/8-24UNF-2B
.50" MIN. DEPTH
PERFECT THD
.360 MAX
.03R
.02 BREAK
.375
.12R
SECTION C-C
SCALE: 2/1
.505 REF
C'BORE OR CAST
TO FIT INSERT
SECTION C-C INSERT
REMOVED FOR CLARITY
NOTES:
1. INSTALL .735 LONG X .500 DIA CRES INSERT WITH THD INDICATED.
2. INSERT MUST MEET TORQUE, PULLOUT & PUSHOUT REQUIREMENTS OF MIL-F-5577B, SECTIONS 3.10.1, 3.10.2 & 3.10.3.
3. MATERIAL: AL. ALY -
CASTING: QQ-A-601, ALLOY 40E OR QQ-A-591, ALLOY A380.
SHEET: QQ-A-250/11, TEMP T6.
4. FINISH: BOTTOM RING ALODINE PER MIL-C-5541.
TOP RING ANODIZE PER MIL-A-8625.
BOTH RINGS COLOR APPROXIMATING 30257, OR 30266 OF FED-STD-595.
THE GOODYEAR TIRE & RUBBER COMPANY
10" x 16" COMPRESSION FITTING
(PILLOW TANKS)
ADP8001T45
NOTED
APPLICATION
ADP8001745C

-20-

V TESTING

The test data on the physical properties of the Kevlar cloth, coatings, coated fabric, seams and fittings is presented in Tables I through V. For comparison purposes the actual data as well as the specification requirements are presented. In general, the actual data exceeds the specification except for a few areas, where results are marginally below specification requirements.

The Kevlar cloth tensile strength is slightly below the 1300 lbs/inch goal for an average of five samples, however, the tensile value range was from 1120 lbs/inch to 1400 lbs/inch.

The new polyester polyurethane has improved hydrolitic properties, and is also lower modulus polyurethane, therefore tensile strength for both original and at 200% elongation is reduced.

The fuel diffusion test on the coated fabric is extremely high, which can be attributed to the buffing and sanding that had to be performed after each spray to obtain a smooth surface finish. It is quite likely that the fuel barrier was buffed or sanded off in certain areas.

The metal peel adhesion samples after immersion in Medium #5 fuel appeared to be low with the failure probably being in the adhesive to the cloth. These tests were rerun to determine the exact mode of failure. This data is shown in Table VI.

All four (4) experimental tanks were pressure tested at one (1) psi and checked with a soap solution for leakage. Two of the containers had minute pinholes resulting from swags and imperfections (yarn damage) in the base cloth. These were repaired and the containers retested. Figures 2 and 3 show the tanks on test.

VI CONCLUSIONS AND RECOMMENDATIONS

The technical feasibility of weaving a seamless Kevlar tube cloth has been demonstrated on an 80-inch wide loom. Many variations of weave types were tried with The 2 x 1 modified oxford weave shown in Figure 6 was selected to meet the goals of the specification. The major difficulties encountered were with warp yarn damage at the tube turn-around edge. The warp yarn damage was significantly reduced on the final tube cloth over earlier trial samples. However, the application of the inner and outer coatings by a spray process requires the cloth to be smooth and free of filament damage. If the cloth has broken filaments the sprayed elastomer adheres to them and produces a very rough surface finish.

Additional development will be required to eliminate and reduce filament damage. Huyck personnel feel that damage would be greatly reduced on production loom equipment, where tighter edge formation technology can be utilized.

On the 80-inch lay-flat tube the adhesive was applied and baked at Goodyear Aerospace Corporation (GAC). However, on production size seamless tubes, this should be accomplished at the weaving mill to reduce handling and possible damage. The problem of adhesive application and handling the tubular cloth at the weaving mills will require further study with the possible addition of new equipment.

Based on this development effort, along with anticipated weaving improvements on production looms, we feel that a quality woven seamless Kevlar tube cloth suitable for use in the fabrication of collapsible fuel containers could be produced. A trial production tube would have to be produced to prove out the expected improvement.

If the filament damage cannot be eliminated completely on the seamless Kevlar tube, then an alternative approach would be to weave the cloth in flat widths up to twelve feet. The utilization of the wider twelve foot cloth would reduce the number of seams by a factor of 3, and therefore, minimize field seam problems.

RF-365

2 x 1 MODIFIED OXFORD

FIGURE 6

TABLE I

CHARACTERISTICS OF UNCOATED KEVLAR CLOTH[1]

PHYSICAL PROPERTIES	TEST METHOD	PURCHASE DESCRIPTION PARAGRAPH	PURCHASE DESCRIPTION REQUIREMENT	ACTUAL DATA
Weave	None		Square 2 x 2 Basket	Modified Oxford 2 x 1
Thread Count, Warp & Fill Single yarns per inch	FTMS-191,[5] 5050		36 x 36	36 x 18
Weight, Ounces/Square Yd	FTMS-191, 5041		Record	9.50
Thickness, MILS	FTMS-191, 5030.2		25 (max)	0.018
Tear Resistance, Tongue Warp by Fill, Pounds	FTMS-191, 5134[1]		125 (min)	264 x 274
Breaking Strength, Ravel Strip, Initial Warp & Fill, Pounds/Inch	FTMS-191, 5104[2]		1300 (min)	1231 x 1283
After 100 Hours Exposure to Accelerated Weathering @ 1% Elongation	FTMS-191, 5804[3]			
Breaking Strength, Warp & Fill, lbs/in.	FTMS-191, 5104			559 x 635
Percent of Initial Breaking Strength Retained			50% (min)	45.4 x 49.5

NOTES:

1. The edges of the tear-test specimen shall be coated by dipping into or brushing with an adhesive that will preclude yarn slipping while under test (see 6.4).

2. Ends of specimens for Breaking Strength Test shall be coated by dipping into or brushing with an adhesive that will preclude yarn slipping under test (see 6.4). Only those parts that are to be held in the clamps during test will be so treated.

3. Alternate Corex D filters removed. Specimens shall be raveled for Method 5104 after accelerated weathering.

TABLE II

PROPERTIES OF CURED ELASTOMERIC COATING COMPOUNDS

Physical Properties		Test Method	Requirements		Actual Data	
Initial						
Tensile Strength		FTMS-601, 4111				
a. 82C39(2)	psi.		4000 (min)		3277	
b. D1666F609(3)	psi.		3000 (min)		3349	
c. 82C09(3)	psi.		2000 (min)		2160	
Stress at 200% Elongation		FTMS-601, 4131				
a. 82C39(2)	psi		1500 (max)		1174	
b. D1666F609(3)	psi		1500 (max)		1160	
c. 82C09 (3)	psi		750 (max)		1189	
Ultimate Elongation		FTMS-601, 4121				
a. 82C39(2)	%		300 (min)		410	
b. D1666F609(3)	%		300 (min)		440	
c. 82C09(3)	%		300 (min)		340	
After Immersion in Distilled Water (ph 7.0 ±0.2) at 160°F ±2°			14 Days	70 Days	14 Days	70 Days
Volume Change		FTMS-601, 6211				
a. 82C39(2)	%		Record	Record	1.6	1.7
b. D1666F609(3)	%		Record	Record	2.2	2.4
c. 82C09(3)	%		Record	Record	1.2	1.0
Initial Tensile(1) Strength Retained		FTMS-601, 6111 Para. 4.8.1				
a. 82C39(2)	%/psi		60	40 (min)	94/3075	82/2697
b. D1666F609(3)	%/psi		60	40 (min)	107/3596	93/3118
c. 82C09(3)	%/psi		50	25 (min)	77/1667	89/1914
After Immersion in Medium #5 at 160° ±2°			14 Days	70 Days	14 Days	70 Days
Volume Change		FTMS-601, 6211				
a. 82C39(2)	%		Record	Record	59.3	71.5
b. D1666F609(3)	%		Record	Record	52.1	63.0
c. 82C09(3)	%		Record	Record	80.4	94.1
Initial Tensile (1) Strength Retained		FTMS-601, 6111 Para. 4.8.1				
a. 82C39(2)	%/psi		40	30 (min)	53/1740	48/1581
b. D1666F609(3)	%/psi		40	30 (min)	51/1696	48/1624
c. 82C09(3)	%/psi		35	25 (min)	58/1261	51/1117
After Accelerated Weathering for 300 Hours (4)		FTMS-191, 7311				
Initial Tensile Strength Retained		FTMS-601, 6111 Para. 4.4.1				
a. D1666F609(3)	%/psi		75 (min)		92/3081	
b. 82C09(3)	%/psi		75 (min)		93/1966	
Fuel Contamination		ASTM D381-70				
Unwashed Existent Gum		ASTM D381-70 Para. 9.1 - 9.6				
82C39(2)	MG/100ML		20 (max)		20.7	
Heptane Washed Existent Gum		ASTM D381-70 Para. 9.8-9.12				
82C39(2)	MG/100ML		5 (max)		7.25	

TABLE II (continued)

NOTES:

(1) The percentage tensile strength retained is:

$$\frac{\text{Tensile strength retained after immersion or weathering} \times 100}{\text{Initial tensile strength value actually obtained (average of 3 or more samples)}}$$

(2) Interior compounds: All compounds between the Kevlar cloth and the inside of the tank. 82C39 (Polyester, Black)

(3) Exterior compounds: All compounds between the Kevlar cloth and the outside of the tank. D1666G609 (Polyester, Tan) 82C09 (Polyester, Tan)

(4) Exposed at 10% elongation with alternate Corex D filters in place.

TABLE III

CHARACTERISTICS OF CURED COATED FABRIC

PHYSICAL PROPERTIES	TEST METHOD	PURCHASE DESCRIPTION PARAGRAPH	PURCHASE DESCRIPTION REQUIREMENTS	ACTUAL DATA	
Thickness, MILS	FTMS 191, 5030.1		30 - 40	0.050	
Weight, oz/sq. yd	FTMS 191, 5041(3)		30 - 40	38.00	
Diffusion Rate, Class I Only fl oz/sq ft/24 hrs		4.4.2	0.05 (max)	0.1330	
Tearing Strength	FTMS 191, 5134				
Warp, Lb.			70	62	
Fill, Lb.			70	66	
Breaking Strength	FTMS 191, 5102(2) 5804				
Warp, Lbs/in			1300 (min)	1255	
Fill, Lbs/in			1300 (min)	1267	
Puncture Resistance, Lbs.	FTMS 191, 5120	4.4.3	300 (min)	311	
After 500 hrs. Accelerated Weathering at 100 lbs/in Initial Breaking Strength Retained					
Warp, % Retention	FTMS 191, 5804(2) 5102(1)		80 (min)	104 (1306 lb/in)	
Fill, % Retention	FTMS 191, 5804(2) 5102(1)		80 (min)	103 (1305 lb/in)	
Low Temperature (-25°F) Crease Resistance					
a. Appearance after unfolding		4.4.4	No cracking peeling or delamination	No cracking peeling or delamination	
b. Diffusion Rate Class I Only fl oz/sq ft/24 hrs		4.4.2	0.05 (max)	0.1392	
Blocking		4.4.5	Test specimens shall separate within 5 seconds	Slight Blocking (Undusted Fabric) No Blocking (Dusted Fabric)	
Fungas Resistance	FTMS 191, 5762(5)				
a. Appearance after burial			No cracking, blistering, or delamination of coated fabric No fungas growth	No cracking, blistering or delamination of coated fabric. No Fungus	
b. Breaking Strength	FTMS 191, 5102(1, 3)				
Warp, % Retention			50 (min)	112 (1401 lb/in)	
Fill, % Retention			50 (min)	105 (1343 lb/in)	
Coating Adhesion Initial Lbs/in (min)	FTMS 601, 8011	4.4.6	20	In/In	Ex/Ex
				Water 28/32	41/40
				Med #5 33/31	42/40
After immersion in distilled water, ph of 7.0 ±2 @ 160°F ±2°F for			14 Days / 42 Days	14 Days In/In Ex/Ex	42 Days In/In Ex/Ex
a. Pounds/inch (min)			10(4) / 5(4)	19/20 36/38	15/15 33/33
			or / or		
b. Percent of initial value (min)			30(4) / 20(4)	67/63 88/95	54/47 80/83
After immersion in MED #5 at(3) 160°F ±2°F for both			14 Days / 42 Days		
a. Pounds/inch			10(4) / 10(4)	15/16 18/17	13/11 15/15
			or / or		
b. Percent of initial value (min)			40(4) / 30(4)	45/52 43/43	39/35 36/38

TABLE III (Continued)

NOTES:

1. Properties after cure.
2. Specimens shall be prepared by stripping two (2) threads from each side of the specimens. (The specimens shall be 1.0 inch wide after removal of threads.) If thread-stripping is not possible, extreme care shall be taken to cut specimens parallel to and following the curvature of the threads of the fabric.
3. Specimens shall be exposed to accelerated weathering before stripping or cutting to 1.0-inch width. (Note 1). Specimens shall be tensioned in the direction of the 6-inch length, under a stress of 100 lb/in ± 5 lb/in for 60 seconds. While still under stress the specimen shall be clamped to maintain the initial (one minute) elongation without slippage. While still so elongated, specimens shall be exposed by Method 5804 of FED. TEST METHOD STD. 191, with the tank exterior coating facing the carbon arc. Alternate Corex D filters shall be removed during test.
4. Whichever is the greater requirement.
5. Method 5762 except that the specimens shall be prepared by Note 1, after soil burial and the number of specimens shall be reduced from 40 to 12. Leaching of the specimens is unnecessary.
6. Medium No. 5 of Method 6001 of FED. TEST METHOD STD. 601.

TABLE IV

CHARACTERISTICS OF CURED SEAMS

PHYSICAL PROPERTIES	TEST METHOD	PARAGRAPH	PURCHASE DESCRIPTION REQUIREMENTS			ACTUAL DATA			
						14 Days		42 Days	
						(Ex)	(In)	(Ex)	(In)
Seam breaking strength, shear adhesion, initial, lbs/in	FTMS-601, 8311	4.4.7	1200[2] (min)			1192			
Seam coat adhesion, initial lbs/in	FTMS-601, 8011		25 (min)		Water	31	21	27	14
					MED #5	27	21	33	17
After immersion in distilled water, ph of 7.0 ± 2 @ 160°F ± 2°F for both			14 Days	42 Days		14 Days		42 Days	
1. Seam breaking strength	FTMS-601, 8311/6001	4.4.7							
a. pounds/in (min)			850	400		1010		924	
						(Ex)	(In)	(Ex)	(In)
2. Peel adhesion	FTMS-601, 8011/6001	4.4.7							
a. Pounds/inch (min) or			10[3] or	5[3] or		22	16	17	8
b. Percent of initial value (min)			40[3]	15[3]		71	76	63	57
After immersion in MED #5 @160°F for			14 Days	42 Days		14 Days		42 Days	
1. Seam breaking strength	FTMS-601, 8311/6001	4.4.7							
a. Pounds/inch (min)			850	400		1095		1106	
						(Ex)	(In)	(Ex)	(In)
2. Peel Adhesion		4.4.7							
a. Pounds/inch (min) or			15[3] or	15[3] or		10	12	11	11
b. Percent of initial value (min)			50[3]	50[3]		37	57	33	64
Dead load shear resistance (initial)									
Slippage or separation under stress of 100 lb/in @ 200°F for 8 hours, inch (max)		4.4.8	0.125			0.00			

NOTES:

1. Properties after cure.
2. All specimens must break in the coated fabric. Failure of any specimen in a seam area at any value shall constitute failure of this test.
3. Whichever is the greater requirement.
4. (Ex) = Exterior

   (In) = Interior

TABLE V

CHARACTERISTICS OF BONDED FITTINGS[1]

PHYSICAL PROPERTIES	TEST METHOD	PARAGRAPH	PURCHASE DESCRIPTION REQUIREMENTS		ACTUAL DATA	
Shear adhesion, fitting to coated fabric bond initial, lb/inch		4.4.9 & 4.4.9.1	1000 (min)		1736	
Peel adhesion, aluminum strip to coated fabric initial, lb/inch		4.4.10	45 (min)		23	
Bond after immersion in distilled water, ph of 7.0 ±0.2, @ 160°F for both			14 Days	42 Days	14 Days	42 Days
1. Shear adhesion						
pounds/inch (min)			700	500	1855	1366
2. Peel adhesion						
a. pounds/inch (min)	FTMS 601, 8031	4.4.10.1	25[2]	15[2]	14	14
			or	or		
b. % of initial value (min)			45[2]	30[2]	61	61
Bond after immersion in MED #5 @ 160°F for			14 Days	42 Days	14 Days	42 Days
1. Shear adhesion						
pounds/inch (min)			400	300	1639	1166
2. Peel adhesion						
a. pounds/inch (min)	FTMS 601, 8031	4.4.10.1	35[2]	30[2]	4.5	2.3
b. % of initial value (min)			60[2]	50[2]	20	10
Dead Load Adhesion						
Slippage or Separation Under 100 lb/in Stress @ 200°F for 8 hours, inch (max)		4.4.9.3	0.125		0.00	

NOTES:

1. Properties after cure
2. Whichever is greater requirement

TABLE VI

METAL PEEL ADHESION RETEST DATA

Peel Adhesion, Aluminum Strip To Coated Fabric		Original	14 Days	42 Days
After Immersion In Distilled Water (ph of 7.0 ± 0.2) at 160°F	lbs/in.	49 (1)	34 (1) 24 (2)	35 (1) 10 (2)
After Immersion In Medium #5 at 160°F	lbs/in.	37 (1)+(2)	18 (1)+(2) 3 (2)	5 (2) 3 (2)

Failure Locations:

(1) Adhesive to Cloth

(2) Adhesive to Metal